COMMENTS ON A MISSISSIPPI VALLEY CYCLOGENESIS

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ABSTRACT

The National Meteorological Center (NMC) surface analysis of a Mississippi Valley cyclogenesis is discussed from two viewpoints; first, as the development of a polar-front wave, and second, as the development of the field of three-dimensional motion in a strong baroclinic zone. It is pointed out that the second approach leads to a more complete and satisfactory portrayal of both the storm's development and the accompanying weather.

1. INTRODUCTION

Operationally useful numerical weather prediction (NWP) products have been available routinely at the National Meteorological Center (NMC) since 1958. These products include NWP constant pressure analyses as well as analyzed fields of vorticity and vertical motion. Use of the NWP analyses has led the NMC staff to look at weather analysis as a direct portrayal of three-dimensional atmospheric motions given by vorticity advection and implied divergence patterns from a simple NWP model. This model is essentially an extension of the equivalent barotropic model in which the thermal advection patterns in the 1000–500-mb. layer are used to modify the equivalent barotropic vertical motions (Part II of [1]). Thus, the NMC staff has to some extent de-emphasized use of the polar front model or more indirect approach to weather analysis. Such a shift in approach has been discussed by Reed [2], and at NMC is most apparent over North America where dense data coverage supports a good NWP analysis of the three-dimensional atmospheric motion. Over ocean areas, where data are sparse, the NMC staff still makes extensive use of the Norwegian cyclone model in weather analysis.

The surface analysis is given the widest and most frequent distribution of all NMC products. Concepts of portraying the surface analysis vary widely in the meteorological community. The Norwegian cyclone model (as summarized in [3]) has many regional variations. Also, interpretation of this model usually varies among meteorologists within each region. Both of these regional and interpretive variations occur frequently in surface analyses of the North American area east of the Rocky Mountains. This paper discusses the NMC surface analyses of a cyclone which developed in the central United States on December 12, 1961. The purpose here is to point out that development of this cyclone departed from the traditional Norwegian cyclone model and that the NMC vorticity, vertical motion, and thickness charts gave a more complete and satisfactory diagnosis of what occurred during the storm's development.

2. ANALYSIS OF THE STORM DEVELOPMENT AS A POLAR-FRONT WAVE

At 1200 GMT on December 11, 1961, the eastern United States was dominated by a large polar anticyclone centered in southern Minnesota (fig. 1A). The polar front at the surface was analyzed by NMC near the coast of the Gulf of Mexico where thermal wind shear and weather criteria indicated the surface boundary of the polar air mass was located (Part I of [1]). The polar air mass was quite shallow and stable as far north as Columbia, Mo., on December 11 (fig. 2). During the next 24 hours, the development of a major cyclone occurred over the central United States as a deepening upper-air trough moved eastward from the Rocky Mountains (figs. 1 and 4). With this type of storm development, described by Palmén [4] several years ago, amplification or development of the thermal wave aloft often precedes surface development. On December 11, 1961, the high stability in the surface polar air mass probably inhibited rapid development of upward vertical motion in the surface layer and consequently suppressed convergence or formation of cyclonic vorticity on the surface chart. Note that the 1000–500-mb. thickness chart (fig. 1C) and 850-mb. isotherms (fig. 3C) for 0000 GMT December 12, 1961 show that amplification of the thermal wave had already taken place several hundred miles north of the surface front in the Gulf States. Figure 1 shows that a small cyclone developed north of the surface front in western Arkansas late on December 11 and moved rapidly toward the lakes. No surface front was associated with this Low during its early stages of development. On the NMC surface chart for 0600 GMT December 12 (fig. 1D), "occlusionogenesis"

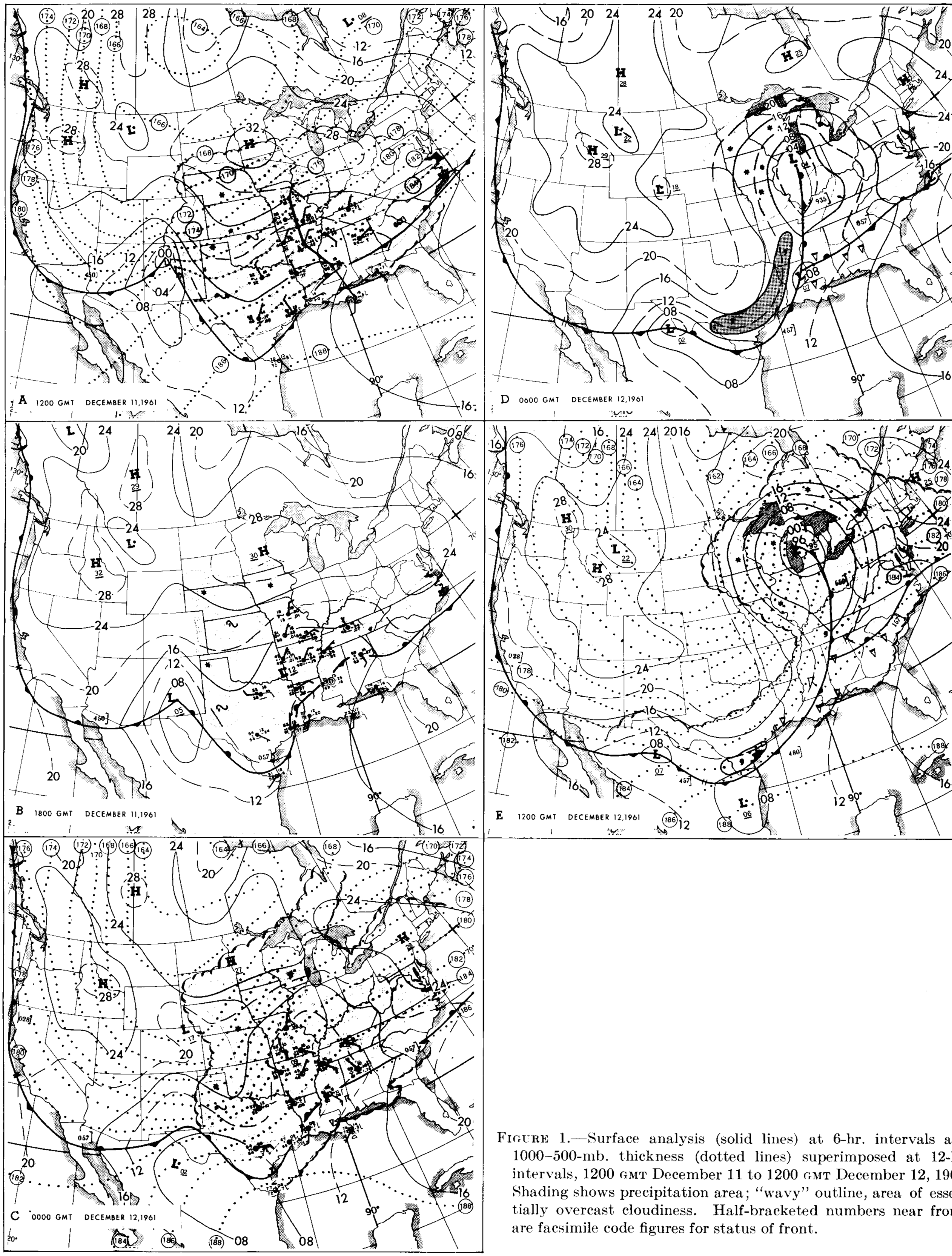

Figure 1.—Surface analysis (solid lines) at 6-hr. intervals and 1000–500-mb. thickness (dotted lines) superimposed at 12-hr. intervals, 1200 GMT December 11 to 1200 GMT December 12, 1961. Shading shows precipitation area; "wavy" outline, area of essentially overcast cloudiness. Half-bracketed numbers near fronts are facsimile code figures for status of front.

(Code: 935) was analyzed as occurring at the surface in this Low.[1]

The occurrence of cloudiness and precipitation over most of the eastern United States during the early stages of this storm (on December 11) is not very well explained by any cyclone model. Also on December 12 the precipitation and cloudiness persisted to the west of the occlusion for several hundred miles in the central Mississippi Valley. Twenty-four-hour precipitation amounts on December 10 through 12, 1961, (fig. 5) were very heavy in the southeastern United States near the east-west polar front. Amounts were relatively light (½ in. or less) over the Great Plains and Mississippi Valley north and east of the

[1] The NMC analyst had difficulty deciding on timing the formation of this occlusion since it had no history at the surface. It was not entered on the early facsimile surface chart until 0900 GMT, December 12. However, the late 0600 GMT facsimile chart (fig. 1D) did show "occlusionogenesis."

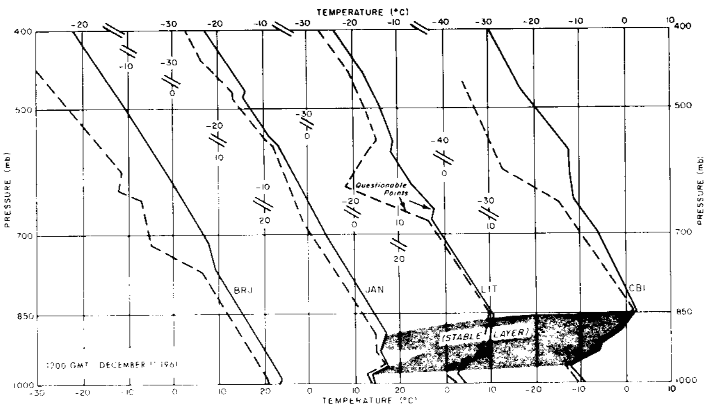

FIGURE 2.—Upper air soundings at Burrwood, La. (BRJ), Jackson, Miss. (JAN), Little Rock, Ark. (LIT), and Columbia, Mo. (CBI), 1200 GMT, December 11, 1961. Solid lines give temperature and dashed lines dew point curves.

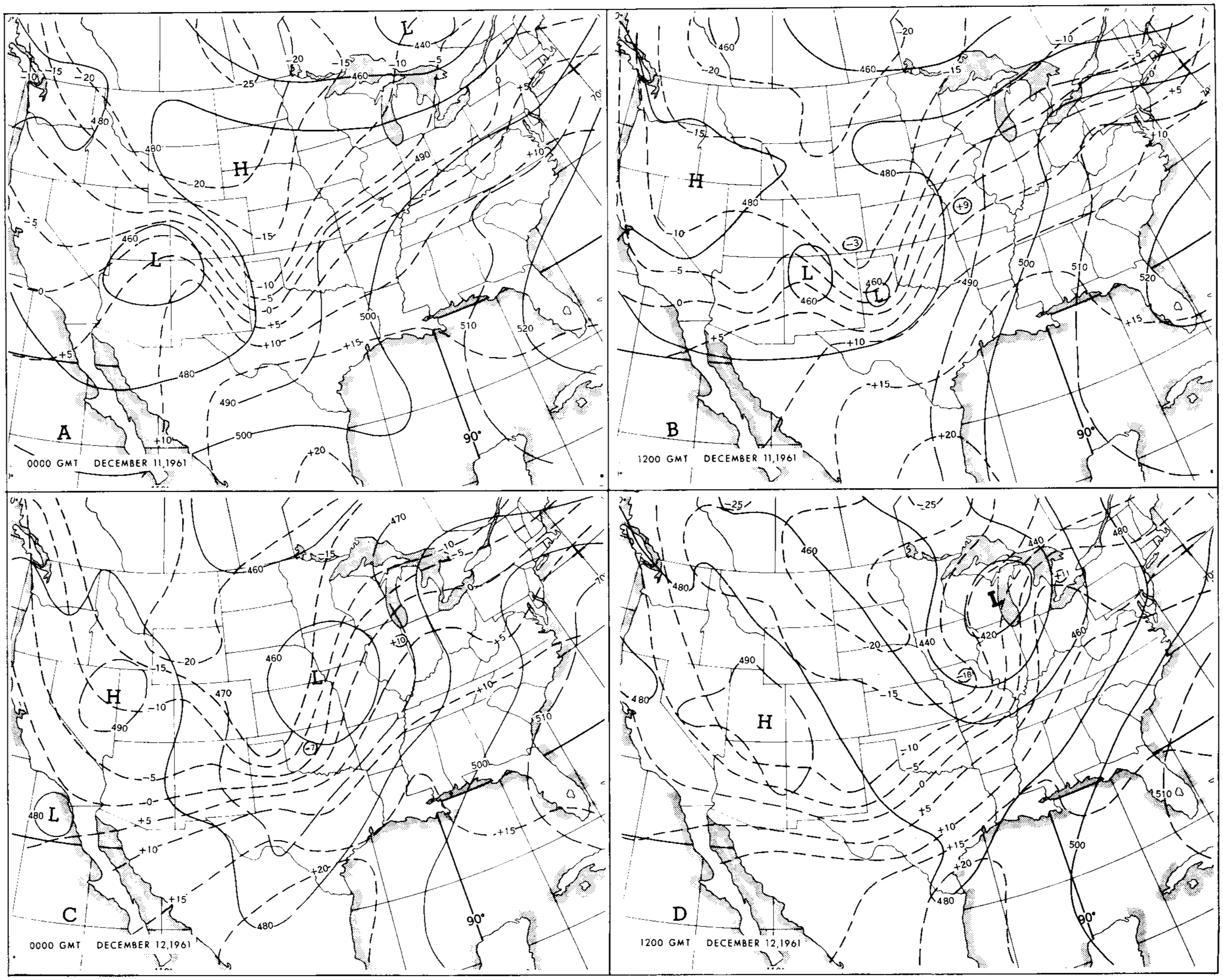

FIGURE 3.—850-mb. charts at 12-hr. intervals from 0000 GMT December 11 to 1200 GMT December 12, 1961. Circled values give location, sign, and amount of maximum 12-hr. temperature changes.

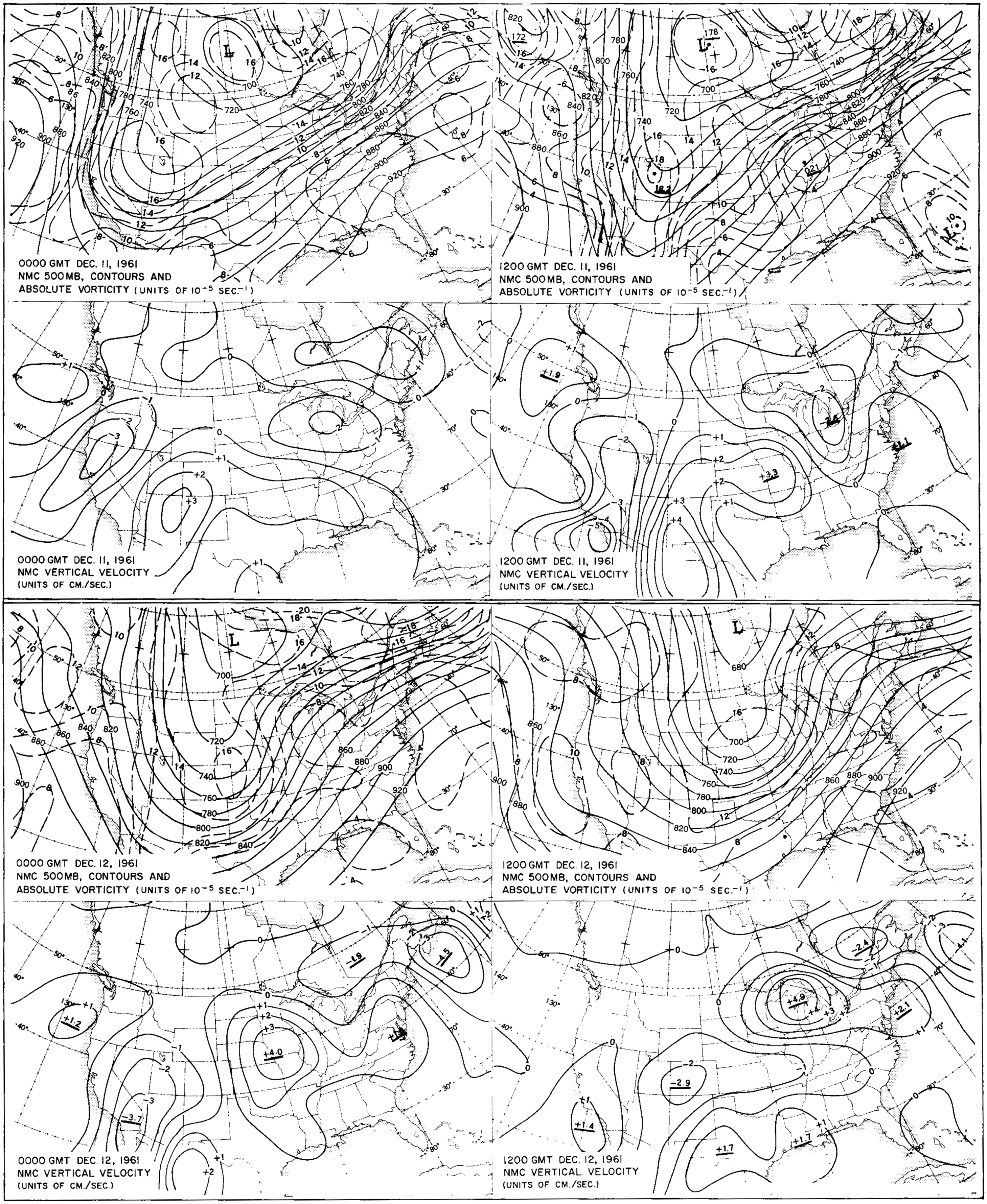

FIGURE 4.—Charts of 500-mb. contours (solid) and superimposed absolute vorticity (dashed lines) and concurrent charts of vertical velocity, at 12-hr. intervals from 0000 GMT December 11 to 1200 GMT December 12, 1961.

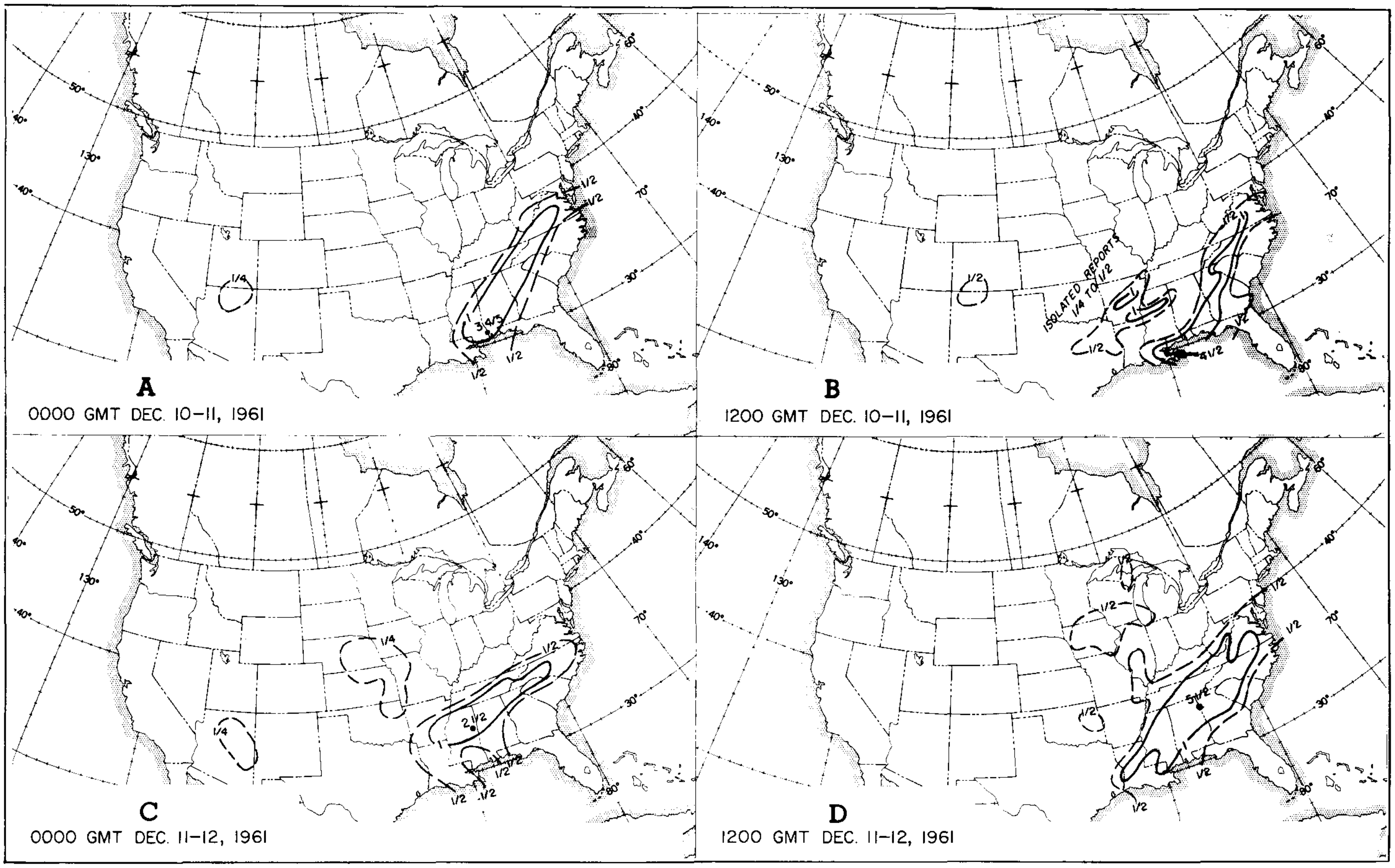

FIGURE 5.—Twenty-four-hour precipitation amounts (inches) in period 0000 GMT December 10 to 1200 GMT December 12, 1961. Maximum precipitation amounts indicated by dots at appropriate locations.

developing cyclone. Here, the available moisture played a key role in the amount of precipitation that fell. An adequate diagnosis of precipitation amounts could not have been based on typical distribution of precipitation with the cyclone model.

3. ANALYSIS OF DEVELOPMENT OF THE THREE-DIMENSIONAL FLOW WITH THE STORM

One of the key analyses at NMC is the 1000–500-mb. thickness chart. As pointed out in section 2, it is used specifically as an aid in placing surface fronts. However, a more general function of this chart is to locate major baroclinic zones defined in terms of strong thermal shear, or thickness "packing" (Part I of [1]). At 1200 GMT December 11 (fig. 1A) the major baroclinic zone existed from the central Rockies across Kansas, northern Missouri, and Illinois to the lower Great Lakes. It was near the southern boundary of this baroclinic zone (over western Arkansas) that the new cyclone first appeared at the surface (fig. 1B). The flat stable wave on the surface polar front over Louisiana changed little in intensity or position during the period of development. The Arkansas cyclone moved northward across the baroclinic zone and deepened rapidly near the center of the zone (fig. 1E) where the advection of thermal vorticity was increasing most rapidly [5], [1]. The NWP 500-mb. absolute vorticity charts in figure 4 show the increase in magnitude of the 500-mb. vorticity advection over the central Great Plains as the storm developed.

Comparison of figures 1 and 4 shows that the occurrence (non-occurrence) of precipitation and cloudiness at 1200 GMT December 11 east of the Rocky Mountains was well correlated with the large-scale 500-mb. positive (negative) vorticity advection and the NWP computed upward (downward) vertical motion. An exception occurred over much of Texas where precipitation was occurring with negative (anticyclonic) 500-mb. vorticity advection, implying descending motion. However, the NWP computed vertical motion was small but still upward over Texas. At 1200 GMT December 12 (fig. 1E) the clearing line occurred several hundred miles behind the occlusion over the upper Mississippi Valley. However, it agreed well with the line of change of sign of 500-mb. vorticity advection over western Iowa and Missouri (fig. 4).

The NWP vertical velocities over the southeastern United States during December 11 and 12 were relatively weak.[2] This upward motion, combined with an ample supply of moisture (1.0 to 1.25 in. of integrated precipitable water between 1000 and 500 mb.) and low stability (Showalter Index: 0 to 4), produced the heavy amounts of precipitation in the southeastern United States shown in figure 5. Over the central Great Plains the NWP vertical motions were relatively large but there was less than ½ in. of precipitable water observed below the 500-mb. level. As a consequence, 24-hr. amounts of precipitation were near or below ½ in. (water equivalent).[3]

4. SUMMARY AND CONCLUSIONS

The storm of December 11–12, 1961, developed as a special case of the Norwegian cyclone model. Such developments occur frequently in the central United States and have been described by Palmén [4]. Portrayal of the December storm on the NMC surface chart was difficult using the traditional Norwegian model. More important, the model failed to explain the major areas of precipitation and cloudiness accompanying the storm. A more complete and satisfactory diagnosis of the storm's development, including cloudiness and precipitation, was possible by making use of a simple extension of the equivalent barotropic model (Part II of [1]), which considers temperature advection and vorticity fields in the atmosphere and what they mean in terms of the macroscale vertical motion.

[2] The NWP vertical motions represent a mean motion in the 850-500-mb. layer. Vertical velocities for the 1000-500-mb. layer which are computed routinely at NMC from Sutcliffe's [5] equation, using a scheme devised by Sawyer and Matthewman [6], indicated a large 10 cm. sec.$^{-1}$ center of upward motion over the southeastern United States on December 11 and 12. It should be noted that the NWP vertical velocities shown in figure 4, are computed using a standard atmosphere value for stability, while a neutral value for stability (with respect to saturated parcels) is assumed in the Sutcliffe computations. This neutral value is probably closer to what occurs in nature during precipitation, so the 10 cm. sec.$^{-1}$ value is a better estimate of actual vertical motions over the Southeastern States.

[3] Over Iowa and Wisconsin 4 to 8 in. of snow fell on December 11 and 12.

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